DPP10-2010-001155

Abstract for an Invited Paper
for the DPP10 Meeting of
the American Physical Society

Three-dimensional equilibria and transport in RFX-mod: a description using stellarator tools

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RFX-mod self-organized Single Helical Axis (SHAx) states, spontaneously obtained at high plasma current up to 2 MA, provide a unique opportunity to advance 3D fusion physics and establish a common knowledge basis in a parameter region not covered by Stellarator and Tokamak. VMEC code was adapted to reversed-field pinch (RFP) to model SHAx equilibria, which have a helical core embedded in an almost axisymmetric boundary. Feedback control of helical magnetic field reinforces persistency of 3D shaping, which also increases with plasma current. The helical region boundary, corresponding to an electron transport barrier with zero magnetic shear, high flow shear and improved confinement, is investigated using numerical codes common to the stellarator community. The experimental electron heat diffusivity ($\approx 10m^2/s$ at the barrier), computed by the ASTRA code in 3D coordinates, decreases with plasma current and corresponding residual chaos reduction. The averaged particle diffusivity $\bar{D}$ over the helical volume, estimated with the Monte-Carlo code ORBIT, is consistent with experiment and increases with collisionality. $\bar{D}$ does not show the $1/\nu$ trend of un-optimized stellarators because of de-trapping mechanisms and the absence of superbananas due to negligible helical ripple in the edge. Furthermore, DKES code is being adapted to RFP for local neoclassical transport computations, including radial electric field, in order to estimate diffusion coefficients in the barrier region for typical RFX-mod temperature and density profiles. No change of impurity transport is found, which is consistent with fully collisional transport, and experimentally with a hollow impurity profile and edge-peaked radiation measurements, as in LHD. Analytical and numerical tools like GS2 indicate that small-scale turbulence contributes to drive anomalous transport in the barrier region. Thermal conductivity estimated from microtearing modes is consistent with experiment.